Gage (S. H.)

THE AMPULLA OF VATER

AND THE

Pancreatic Ducts in the Domestic Cat

(*FELIS DOMESTICA*).

BY

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With the Compliments of

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The reader will please make the following corrections :

Page 3, line 24, for (7, I., 794) read (4, I , 794).

" 5, last line, for Fig I., 1 and 2, read Fig II., 7 and 2.

" 7, line 9, for (1,585) read (5,585)

" 7, line 18, for *mesenteric* read *peritoneal.*

" 9, line 6, for (32,297) read (32,350)

" 10, Plate XIII , *b*, for *mucasæ* read *mucosæ.*

" 13, line 7, for *bond* read *band.*.

" 19, line 1, for *aut* read *aux.*

THE AMPULLA OF VATER AND THE PANCREATIC DUCTS IN THE DOMESTIC CAT (*Felis domestica*).*

BY SIMON H. GAGE, B. S.

(*Received December 19, 1878.*)

As with nearly all organs, the pancreas and its ducts were first carefully investigated in man, therefore, it is necessary to turn to the history of human anatomy for the first exact knowledge upon the subject of this paper.

Anatomists attribute to G. Wirsung the discovery, in 1642–3, of a pancreatic duct in man, opening into the duodenum with the ductus choledochus (37 and 1, 383).†

Vesling, in 1664 (35 and 22, 509), and DeGraaf again in 1671,

DESCRIPTION OF PLATE XII.

All the figures original except III.

Fig. I. Natural size, from an adult female cat, seen from the ventral surface. The great omentum, the jejunum, ileum, colon, and liver removed; the remaining parts shown *in situ*. The duct of Wirsung was afterwards injected with Berlin-blue, and both it and the duct of Santorini dissected out to show their branches and anastomoses.

1. Pyloric region of the stomach.

2. Pylorus. 2–3. The duodenum.

4. Gastro-splenic division of the pancreas, near the main branch of the duct of Wirsung.

5. The duodenal part of the pancreas and branch of the duct of Wirsung.

6. Duodenum at the point where the duct of Santorini pierces its walls. The dotted line shows the extent of the pancreas on the dorsal side of the intestine. The duct of Santorini is seen to anastomose with each division of the duct of Wirsung.

7. Ductus communis choledochus.

8. The point where the ductus choledochus and duct of Wirsung enter the duodenum.

9. Tip of the spleen, somewhat displaced.

10. The superior mesenteric artery sending the inferior pancreatico-duodenal branch to those parts.

11. Superior mesenteric vein receiving a corresponding branch.

Fig. II. Natural size, from an adult female cat. The liver turned to the right bringing the concave side up, the duodenum to the left, so that its right side looks directly upward, and then sliced off to the level of the ampulla of

*This paper is based upon investigations made in course of the preparation of a Manual for the Dissection of Cats, by Prof. Burt G. Wilder and the writer.

†See list of works referred to at the end of this paper. The first figure designates the number on the list; the last, the page; the middle, Roman numeral, the volume.

showed that in man there were sometimes two ducts, the larger opening in common with the ductus choledochus, and the smaller independently. Several others of the earlier anatomists noted the same fact, but, like Vesling and DeGraaf, considered the presence of two ducts anomalous.

Sometime before the year 1752, Vater, a Dutch anatomist, described an enlargement or diverticulum of the ductus choledochus in its passage through the duodenal walls, and stated that into this enlargement the duct of the pancreas, described by Wirsung, emptied (34 and 22, 455). This enlargement has been named after its discoverer, the *Ampulla of Vater*.

To resume the subject of the pancreatic ducts, it is to Santorini, 1775, that we owe the idea of the normal presence of

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Vater, and the duct of Santorini. When right or left is used, it is the right or left of the cat that is meant.

1. Plyorus.
2. The duct of Santorini passing obliquely through the duodenal walls.
3. Cut end of the inferior pancreatico-duodenal artery.
4. Same for the corresponding vein.
5. The duodenal branch of the duct of Wirsung.
5. Cut end of the duodenal pancreas, showing triangular section, and the intestines partly enveloped.
6. The ampulla of Vater.
7. The duct of Wirsung opening into the ampulla.
8. The ductus communis choledochus, also opening into the ampulla.
9. The duodenal branch of the duct of Wirsung.
10. The gastrosplenic branch.
11. Duct from the pancreatic reservoir opening by a large branch into 10, and by a small one into 7.
12. Pancreatic reservoir covering part of the gall-bladder.
13. The "impeding flexures" in the cystic duct.
14. The gall-bladder constricted in the middle, as is also the pancreatic reservoir, by a firm wide band passing over them.
15, 15. The cystic lobe of the liver.

Fig. III. Half natural size, from an adult man (After Bernard). Ventral view. The wall of the duodenum partly removed to show the openings of the ducts, which have been exposed by dissection.

1. Pylorus.
2 and 4. Duct of Wirsung.
3. Duct of Santorini anastomosing freely with the preceding, and opening into the intestine between the aperture of the ampulla of Vater and the pylorus.
5. Ductus communis choledochus.
6. Opening of the duct of Santorini at the summit of a papilla.
7. Opening of the ampulla at the summit of a similar papilla. These openings are usually about 10-15 mm. apart.

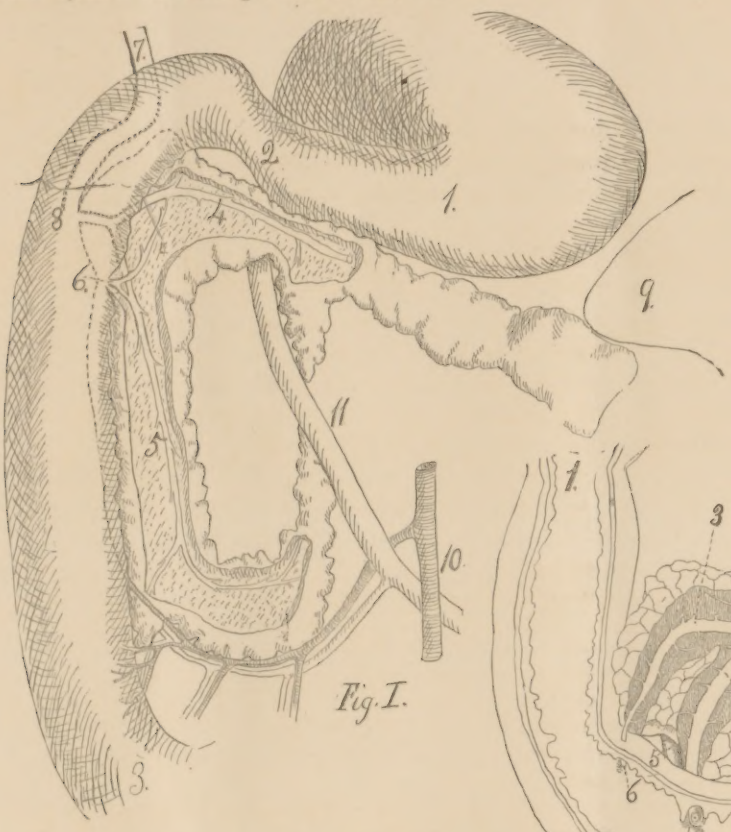

Fig. I.

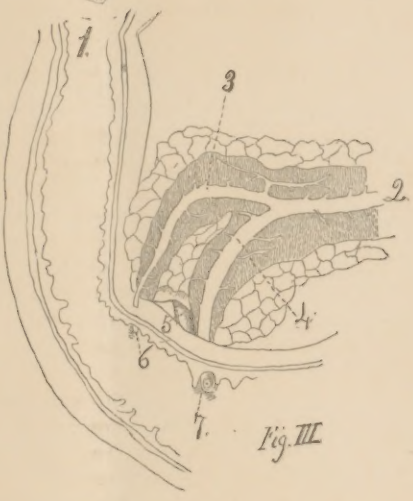

Fig. III.

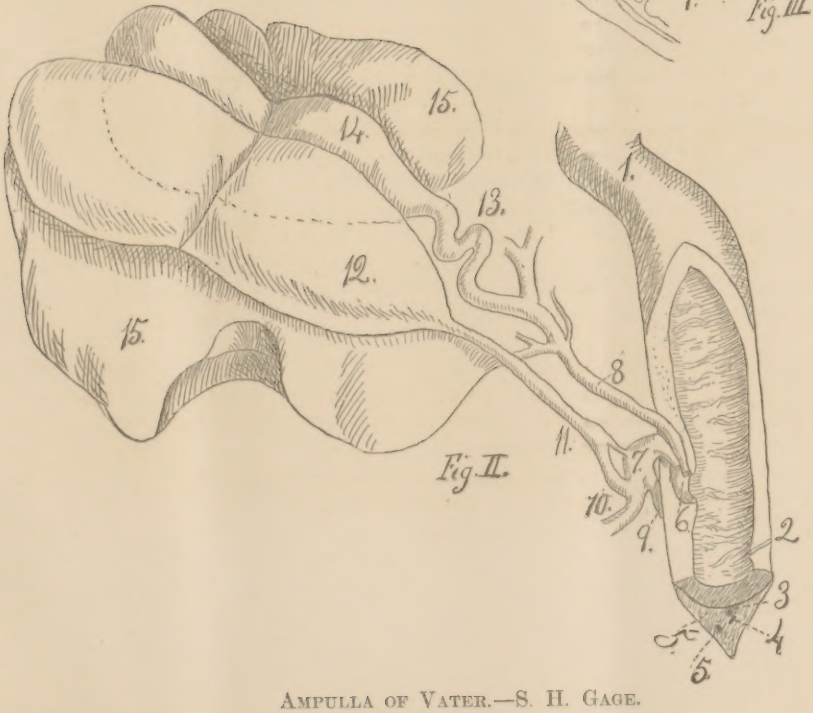

Fig. II.

Ampulla of Vater.—S. H. Gage.

two ducts. He figured the pancreas and the two ducts, with their mode of opening; viz., the larger into the ampulla of Vater, with the ductus choledochus, and the smaller independently into the duodenum nearer the pylorus than the ampulla of Vater (28 and 1, 383). The description and figures of Santorini seem to have been forgotten or ignored down to the time of Cl. Bernard, in 1846 (1, 383). At this period, the opinion was universal that the presence, in the adult, of two ducts opening separately was anomalous; and, although Meckel had shown conclusively in 1835 that two ducts constantly exist in the human fœtus, he supposed that one of them normally atrophied, and that its presence in the adult was merely an unusual persistence of the fœtal condition (20, 316, 317, 474 and 476). He was followed in this opinion by all anatomists.

Bernard called attention to the constant presence of two ducts in the adult, and his observations, which were very numerous, together with those of several other great anatomists, have shown that the absence of two ducts is the exceptional condition in the adult human being (18, 1137; 1, 385, 22, 509; 29; 10, 331 and 38). It is necessary to state that some modern anatomists and physiologists do not coincide with the above opinion, although they recognize the occasional presence of a second duct. Among these may be mentioned Quain (25, II., 396), Gray (14, 793), Colin (7, I., 794), Hyde Salter (27, 85), and Owen (23, 497). Prof. Owen looks upon the anomalous (?) second duct as an indication of the homology of the so-called head of the human pancreas with the duodenal pancreas of the lower mammalia.

With reference to the mammalia below man, Marshall (19, 595) has made the important generalization that the normal number of pancreatic ducts, opening independently into the duodenum, is two. Milne Edwards (22, 510), in confirmation of this idea, says: "Until lately, it was thought that with all the ruminants there was but a single pancreatic trunk, but it is now known that in the ox there are ordinarily two ducts opening separately, and sometimes even three; and it is probable that careful investigation will reveal a similar condition in many other mammals." This idea is further supported by the fact that with the animals most fully studied there have been found normally two pancreatic ducts, at some time of life at least. This is the case with man, the horse, dog, cat, and many others (1, 383; 22, 508; 23, 492; 27, etc.).

It is evidently necessary in both human and comparative anatomy to be able to designate the two pancreatic ducts, so that there can be no doubt as to which is meant in a given case. There would be no danger of confusion, if in all species and all individuals of the same species, the relative size and position of the ducts were invariable; but this is not the case, for in man (Plate XII., Fig. III.,) the duct opening separately into the intestine is normally nearer the pylorus than the one opening in common with the ductus choledochus, while in all other mammals, where two ducts are known, neither opens nearer the pylorus than the ductus choledochus. It should be stated, however, that both Owen (23, 497) and Salter (27, 85), figure and describe the independent second duct in man as opening into the duodenum "below," farther from the pylorus than the one opening in common with the ductus choledochus, as is the case in the lower mammals, although it may rarely open nearer the pylorus. But Santorini (28), Bernard (1, 384), and Robin (18, 1137), figure the ducts, and state very positively that the one opening independently is always nearer the pylorus ("au-dessus, mais non au-dessous") than the one opening with the ductus choledochus. Flint (10, 331) and Dunglison (8, 750) give the relative positions as the authors last mentioned.*

In nearly all the works which may be considered original (1, 3, 5, 22, 23, 25, 27, etc.), the ducts, in man and other mammals, have been called "principal" and "accessory." As in many instances, where parts of the human body have been named with reference to their size alone, so in this, comparative anatomy has shown that the lesser, while keeping the same relative position, often becomes the greater, and the

*Note by Professor Wilder. "I gladly avail myself of Mr. Gage's invitation to add a note at this point. How is it that the hundreds of human subjects annually dissected in our medical schools yield so few facts of physiological importance? Why, for example, has not the present question as to the normal number and relative position of the pancreatic ducts of man been settled long ago?

Three reasons occur to me: 1. The general attraction among medical students is toward surgery rather than medicine; hence, they pay more attention to surgical anatomy than to physiological anatomy. 2. The viscera of human subjects are rarely in condition, when removed, to furnish accurate information, and are usually thrown away after a brief inspection. 3. The average medical student is rarely qualified for the proper examination of viscera. If he has had any preliminary training at all, it has referred chiefly to bones and muscles.

Now, if the viscera were removed at an earlier stage of the dissection, such parts as the duodenum might easily be preserved in alcohol, for careful study. In the second place, the viscera of the cat are so nearly like those of man that there is really no reason why they should not first be examined as to both the gross anatomy and the histology of the various organs."

greater the lesser; hence, if the names are retained they can merely indicate that there are two of a kind and one is larger than the other, without any regard to absolute or relative position. The pancreatic duct opening with the ductus choledochus, is called, in man, the duct of Wirsung or the principal duct, and the other the accessory or minor (1, 384; 14, 793; 22; 51; 23, 497; 25; 27). It not unfrequently happens that the duct opening with the ductus choledochus is smaller than the one opening independently, which is now, from its size, called the principal duct, and the other is called the accessory duct, for the same reason (1, 386 and Plate XIII., Figs. I., II.,) (6, 172). Take, for example, this remark of Dalton's; "Even in the human subject, as shown by Bernard, Kölliker, and Sappey, there is often a small accessory duct opening into the intestine, sometimes above (nearer the pylorus) and sometimes below (farther from the pylorus) the situation of the principal one" (6, 172). If one has in mind the statements of Salter (27, 85) and Owen (23, 497), that the accessory or smaller duct opens independently into the intestine at a point farther from the pylorus than the common opening of the ductus choledochus and duct of Wirsung, he might properly suppose that the duct opening with the bile-duct remained constantly the larger, while the small duct opened independently into the intestine, sometimes nearer the pylorus and sometimes farther from it. Taking the statements of Bernard (1, 384) and Santorini (28; 1, 383, also 8 and 18) that the duct opening independently, or the accessory duct, is *nearer* the pylorus than the one opening with the ductus choledochus, the alternative is left to suppose that the duct opening with the ductus choledochus may sometimes be smaller than the other, and for that reason be called the accessory duct, while the other, from its size, is now called the principal duct. The figure added by Dalton (6, 172, Fig. 46) showed this last to be the meaning.

If we turn to comparative anatomy, the confusion is nearly as great, for in dogs the larger duct opens independently at a considerable distance farther from the pylorus than the ductus choledochus, and the smaller opens also on the same side, but very close indeed to the ductus choledochus (1). In the cat the case is reversed, the larger duct opening into the ampulla of Vater, and the smaller one independly and farther from the pylorus (Pl. XII., Fig. I., 1 and 2).

If in these cases we use terms to designate size, there can be no reference to position, either absolute or relative, and hence no comparison. It seems to me that all difficulty may be avoided by choosing two fixed points by which to determine the positions and names of the pancreatic ducts. The pylorus has already served as one point, and the ductus communis choledochus, which is single in all mammals so far as I know, may serve as the other.

As Wirsung was the discoverer of the pancreatic duct in man, which opens into the intestine with the ductus choledochus, that duct in all mammals which opens with or nearest it, may be properly called the duct of Wirsung. This name is recognized, at least as a synonym, by most anatomists (1, 3, 14, 20, 22, 23, 25, 27, etc.). And as Santorini was the first to accurately describe and figure a second duct in man, opening separately into the intestine, the duct so opening independently and the farther from the ductus choledochus, may be called, in all mammals, the duct of Santorini, without regard to its size. This name is also recognized by good authority (8, 750 and 18, 1137).

To briefly recapitulate: Comparison, both in human and comparative anatomy, would always be easy and intelligible if, where two pancreatic ducts are known to exist, the one opening with or next the ductus choledochus, were called the duct of Wirsung, and the one opening independenly and farthest from the ductus choledochus were called the duct of Santorini, without regard to size. Where but one duct is known, it should probably be called the duct of Wirsung.*

The form, position, and relation of the cat's pancreas may be well shown, as in Plate XII., Fig. I., by killing a fasting animal with chloroform, and securing it on its back with the legs horizontal and at right angles to the trunk. After it has stiffened, if the abdominal wall be removed, the great omentum turned over upon the thorax, the liver over the right hypochondrium, turning the concave side uppermost, and the jejunum and ileum into the left hypogastrium, the pyloric region of the stomach with the pancreas and duodenum will appear *in situ*. The pancreas (Pl. XII., Fig. I., 4 and 5) consists of two main divisions, one of which extends from the pylorus along

*For a consideration of the necessity of uniformity in anatomical nomenclature, see Quain (25, I., 20), Pye Smith in the *Journal of Anatomy and Physiology* (30, 15), and Wilder (36).

the pyloric region of the stomach to the spleen, by which its left ventral surface may be partly covered, while its dorsal surface rests upon the left kidney. The second division extends from the first, parallel with the left side of the duodenum, to the inferior pancreatico-duodenal vessels (Pl. XII., Fig. I., branches of 10 and 11). It then curves toward the left, and finally sends a narrowed part along the right side of the superior mesenteric vein (Fig. I., 11), nearly meeting a spur from the first division.

Following Cuvier (1, 585), Hyde Salter (27, 99), and Owen (23, 495), these parts of the pancreas will be named from their relations, the *gastro-splenic* and *duodenal* divisions.

The duodenal division of the pancreas is very thick next the intestine, and envelops about one-third of its circumference, while its free edge is very thin, thus giving a triangular appearance in a cross-section (Fig. II., 5).

Differing from the human pancreas, which is only covered on the ventral surface by the mesentery(25, II., 395; 27, 83), the cat's pancreas has a complete mesenteric investment, the duodenal division being enveloped by the duodenal mesentery, and the gastro-splenic by the dorsal fold of the great omentum.*

The ducts of the pancreas are imbedded in the gland substance throughout their entire extent. The duct of Wirsung extends about a centimeter from the intestine, and then divides into two nearly equal branches, one going to each division of the pancreas (Fig. I., 8, 4, 5). The duct of Santorini is usually very much smaller in the cat than the preceding, and always opens independently into the intestine at a point upon the left side and farther from the pylorus than the common opening of the ductus choledochus and the duct of Wirsung. The two ducts anastomose very freely (Fig. II., 4, 5, 6). The relative positions of the two ducts are accurately shown in Fig. II. There is a spur of gland substance following each duct to the intestinal wall, and clinging very closely to the duct until it penetrates the intestine (Fig. I., 6, 8). At all other points the pancreas is held to the duodenum only by the mesentery, numerous small blood-vessels and loose connective tissue, and can be very easily separated, save where the ducts enter. The

*This seems to be the normal condition in the Felidæ, judging from Prof. Owen's statement: "The pancreas in the feline tribe is composed of two parts, both having an entire investment of peritoneum" (24, 132).

duct of Wirsung is easily found, as it is large and close to the ductus choledochus (Figs. I., II., 7, 8).*

The duct of Santorini is usually much smaller than the preceding, and is, therefore, more difficult to find, especially as there is often an artery of about its own size piercing the intestine near it. It may be found without much difficulty, however, by carefully tearing away the mesentery on the ventral surface of the duodenal pancreas, when one point will be found where a spur of the gland substance clings to the intestine; in this the duct is inclosed. The artery spoken of above is not so imbedded in the gland tissue, and therefore need not be mistaken for the duct. It may seem unnecessary to be so strenuous as to the duct of Santorini, but when it is remembered that the ducts very freely anastomose, it will be seen that no crucial experiment could be made to determine the effect of shutting off the supply of pancreatic juice if either of the ducts were left open. See the experiments of Schiff, rendered inconclusive by ignoring one of these ducts (15, 353)

In Plate XII., Fig. II., 12, is shown, actual size, a curious anomaly in the cat; viz., a *pancreatic reservoir*, analogous to the gall-bladder. In this case it is larger than the latter and partly covers it. The two are very closely bound together for about half their longitudinal extent, by a broad, firm band, which produces a decided constriction in both. The walls of the reservoir are very firm and thick, as are also those of its duct (Fig. II., 11). The duct is nearly straight, and bifurcates before terminating, sending the larger branch to the gastro-splenic division of the duct of Wirsung, and the smaller to the common trunk (Fig. II., 11, 7 and 10). The communication between the pancreatic reservoir and the duct of Wirsung seemed to be entirely free, as air or liquid could be readily forced in either direction. There was no communication whatever between the pancreatic reservoir or its duct and the gall-bladder or the ductus choledochus. But one instance is on record of the presence of a similar reservoir, and that case was described and figured by Mayer in 1815 (21, 297, Tab. III., Fig. 4). Its size relative to the gall-bladder was less, and the duct terminated in the trunk of the

*In fresh animals, the ductus choledochus may be made very obvious by pressing on the gall-bladder so as to fill it with bile.

duct of Wirsung without bifurcating. In all other respects that case seems to be identical with the one just mentioned.

So far as I know, this anomaly has been found only in the domestic cat. Its reported presence in the common seal (*Phoca vitulina*) by Cuvier (5, 587), Salter (27, 99), and Milne-Edwards (22, 511) is probably an error; for Fr. Tiedemann (32,297), to whom they refer for their authority, states that the ductus choledochus, after entering the duodenal wall dilated between its coats forming a larger reservoir, into which emptied the pancreatic duct. He says of this reservoir that it bears great resemblance to that which appears in the gall-duct of the elephant as described by Pierre Camper (39). Owen (23, 480) and Miall and Greenwood (40) say of the elephant: "There is no gall-bladder, but the ductus choledochus expands in the wall of the duodenum into a sacculated pouch, which receives also the first pancreatic duct;" and Prof. Owen says of the seal (*Phoca vitulina*) dissected by him: "The ductus communis was one and a half inches long; it was joined by the pancreatic duct as it terminated in a dilated sacculus *within* the *duodenal coats*," (23, 487). It seems to me evident from all the above that Tiedemann simply referred to a large ampulla of Vater (See Pl. XII., Fig. II., 6, and Pl. XIV., Fig. 1).

MICROSCOPIC ANATOMY.

The ducts of the pancreas are quite variable in size, but the average for the duct of Wirsung is about 2½ mm. and 1 mm. for the duct of Santorini. The inner surface of the duct of Wirsung is usually thrown into longitudinal folds. It is composed of three tolerably distinct layers (Pl. XIII., Fig. 3, *a*, *b*, *c*). The inner layer of epithelium is composed of but a single layer of broad low cells with a very large clear nucleus, and a granular nucleolus. Many of the cells are divided at the base (Pl. XIII., Fig. 6, d), and alternating cells may have their thicker extremities turned in opposite directions. There is no sign of a striated margin as in Pl. XIII., Fig. 5.

The middle coat is very complex, but its main tissue is the elastic. The fibers run both longitudinally and circularly. The longitudinal fibers are quite coarse, while the circular ones are very fine, and by their anastomosing make a complete network. The middle coat is especially dense next the epithelium, and contains many roundish nuclei, which take a deep color in

staining. The vascular supply of the pancreatic duct is very great, and so thickly are the vessels placed that the middle coat seems to be half composed of them (Pl. XIII., Fig. 4).

Finally, the outer layer is made up of areolar tissue which becomes very loose and indefinite toward the outside, but toward the middle layer it is quite dense, and receives many anastomosing, circular, elastic fibers from that coat. Its fibers are likewise both circular and longitudinal. The vessels entering it are comparatively large and go straight through to the middle layer. The nuclei in this layer are less numerous than in the middle one (Pl. XIII., Fig 3, *c*).

In the branches of the duct, the middle layer becomes relatively thicker, and the outer coat is composed mostly of longitudinal fibers.

PLATE XIII.

All the Figures original, and drawn by camera lucida.

Figures 1 and 2 are lettered alike, but their corresponding parts point in opposite directions.

Fig. 1. Stained in hæmatoxylin. Section nearly at right angles to the duct of Santorini in its passage through the intestinal walls (Pl. XII., Fig. 2). The narrower end is the surface of the papilla, exclusive of the mucous membrane, upon which the duct opens. The wide end is toward the muscular coat. ×48.

b. Muscularis mucasæ cut obliquely.

c. Sub-mucous connective tissue.

d. Slender bundles of unstriped muscles rising toward the mucous surface, and surrounding the duct.

e. Cross section of the duct.

f. A band dividing the lumen into two parts.

Fig 2. Stained in hæmatoxylin. A section like the preceding, but near the termination of the duct. ×48.

a. Transverse section of the glands or crypts of Lieberkühn.

e. The lumen of the duct very greatly divided by anastomosing folds.

g. Glands of Brunner.

Figures 3 and 4 are similarly lettered, and are a small part of a transverse section of the trunk of the duct of Wirsung, and both sections were made of the fresh duct by means of Rutherford's freezing microtome. Both ×150.

Fig. 3. Doubly stained in picrocarmine and hæmatoxylin.

a. Single layer of short columnar epithelium.

b. Middle coat of the duct, very dense next the epithelium, and composed of circular and longitudinal elastic tissue and blood vessels.

c. External areolar coat composed mostly of circularly arranged connective tissue, with many fine anastomosing elastic fibers.

d. Cross section of two simple glands imbedded in the middle coat.

e. Circular, elastic anastomosing fibers.

f. Cut ends of longitudinal elastic fibers.

Fig. 1.

Fig. 7.

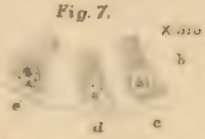

Fig 5.

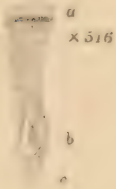

Fig 6.

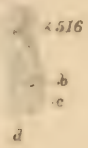

Fig. 2.

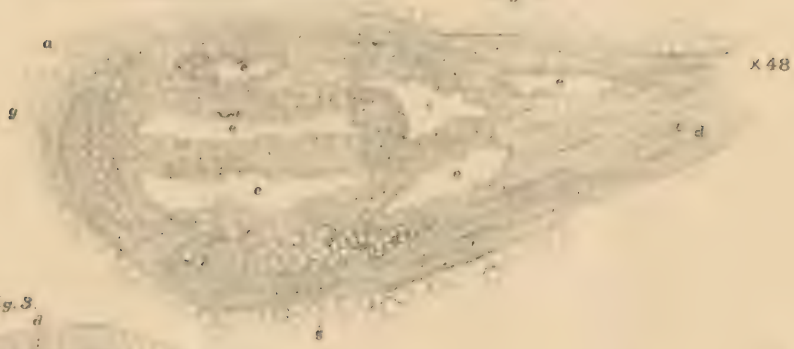

Fig. 3.

Fig 4.

According to J. Arnold, in Stricker's MANUAL of HISTOLOGY (31,150), the pancreatic duct of the cat contains a proper muscular layer, but he does not give its position. Although sections were made of ducts hardened in Müller's fluid and alcohol, and in alcohol alone, and stained with picro-carmine and hæmatoxylin, and doubly stained by these agents, and sections of the fresh duct were treated as above, and with dilute acetic acid, yet no muscular layer or even scattered bundles could be found.

The structure of the human pancreatic duct, as given by Kölliker (17,358), Salter (27,90), Owen (23,497), and Milne-Edwards (22,507), corresponds mainly with the description here given of that of the cat. Kölliker states that the wall of the duct is composed solely of connective tissue with elastic fibers, but Salter says (27,89) that there are a few unstriped muscular fibers in the middle coat, judging from the appearance of nuclei upon the addition of acetic acid, although he was never able to see the fibers satisfactorily.

As the duct of Wirsung approaches the intestine, it nearly meets the ductus choledochus (Pl. XII., Figs. I., and II., Pl. XIV., Fig. 1, *h* and *i*). The two penetrate the intestine a very short

Fig. 4. Stained in picrocarmine. This preparation shows the vascular net work in the duct. Injected with Berlin blue through the superior mesenteric and cœliac arteries.

h. Vascular net work, much denser in the middle coat, and becoming very fine next the epithelium.

Figures 5, 6 and 7. Teased from preparations hardened in Müller's fluid and then in alcohol, stained in picrocarmine. All similarly lettered. All × 516.

Fig. 5. A single granular cell from a villus near the aperture of the ampulla of Vater.

a. Striated border of the free end of the cell.

b. Large, clear nucleus near the narrow, attached extremity.

c. Nucleolus, granular and deeply stained.

Fig. 6. Two cells from the duct of Wirsung. Several groups of cells like this were seen where the broad part of one cell was applied against the narrow part of another, most of them were, however, of nearly equal thickness at the two ends.

d. The divided base of one of the cells. This is common in the ampullar epithelium also.

Fig. 7. Cells from a cross section of a simple glandular depression in the ampulla (Pl. XIV., Fig. 6).

They were drawn in position but set apart somewhat to show the large process (*d'*), fitting under the base of the next cell.

e. Basement membrane.

distance apart, and extend somewhat around it from the dorsal toward the ventral surface, and at the same time obliquely away from the pylorus (Pl. XII., Fig. III., and Pl. XIV., Fig. 1). Within the duodenal wall at this point is quite a large space, the ampulla of Vater, which communicates with the lumen of the intestine by a contracted orifice. The ductus choledochus extends nearly to the orifice of the ampulla before opening, and forms part of its pyloric boundary. The duct of Wirsung, at first separated from the ductus choledochus by a wedge of the muscular coat, is now close to it, and extends parallel with it for a short distance into the ampulla, and then opens (Pl. XIV., Fig. 1). After the two ducts come in contact their walls are fused, and it is impossible to separate them in any way.

DESCRIPTION OF PLATE XIV.

All the figures original, except 2 and 3, which are from Claude-Bernard. They were all carefully outlined by means of a camera lucida, at a distance of 25cm. The magnifying power of the microscope used was computed at the same distance. The same parts are similarly lettered in all the figures of this plate.

Fig. I. A vertical, longitudinal section of the ampulla of Vater, stained in picrocarmine. The duct of Wirsung had been previously injected with Berlin blue. ×10.

a. Villi extending to the edge of the aperture of the ampulla.

b. Crypts of Lieberkühn, growing shorter toward the opening (*f*) on the side of the ductus choledochus.

c. Submucous connective tissue, containing Brunner's glands, and sending a narrow band to the edge of the aperture of the ampulla.

d. Circular layer of muscular fibers, arranged in fasiculi, and cut transversely. It extends along the ductus choledochus on the side next to the pylorus; on the opposite side it thickens and abuts squarely against the duct of Wirsung.

e. Longitudinal muscular layer, extending nearly as far as the ductus choledochus, but becoming thinner.

f. The contracted opening of the ampulla of Vater, which is at the summit of a large papilla.

g. The interior of the ampulla, which is traversed by numerous anastomosing folds and processes, their general direction being *toward* the aperture *f*.

h. The ductus communis choledochus traversing the duodenal wall obliquely from the pylorus, and opening near the aperture of the ampulla. Its interior is divided by numerous anastomosing folds.

i. Duct of Wirsung entering the intestine somewhat less obliquely than the preceding, and opening sooner. The interior contains many anastomosing processes and folds.

j. Narrow wedge of the muscular coats between the two ducts.

Fig. 2. Magnified two diameters. Longitudinal vertical section of the ampulla of Vater in man, from Claude Bernard (1,553, pl. 1, 2, fig. 4 bis). This is said by Bernard to be the normal condition.

Fig. 1. × 10

Fig 2. × 2

Fig. 4 × 15

× 250 Fig. 6.

Fig. 5.

Fig. 3.

At the point where the ducts penetrate the muscular coat, the latter is decidedly thickened. The longitudinal layer parts, allowing the ducts to pass between its fibers, and on the side of the ductus choledochus, the thickening of the muscular layer is due to an addition of special fibers to this layer These fibers interlace in a most complex manner, and extend as a tapering bond along the pyloric side of the ductus choledochus nearly to its orifice. On the side of the duct of Wirsung no such process of fibers is sent along that duct. The circular layer, however, is much thickened on this side, and

h. Ductus choledochus opening at the bottom of the ampulla.

i. Duct of Wirsung opening into the ampulla at the same level as the preceding, but separated from it by a salient fold.

g. The interior of the ampulla with two folds on the side.

f. Orifice of the ampulla.

l, Valvular fold in the duodenal mucous membrane, on the side next the pylorus.

Fig. 3. The same as 2, except that the ductus choledochus is prolonged nearly to the orifice of the ampulla. This is of rare occurrence.

Fig. 4. Section made at right angles to Fig. 1, to show the ducts and ampulla in cross section. Stained in picrocarmine. The duct of Wirsung previously injected with Berlin blue. ×15.

h. Transverse section of the ductus choledochus, which is enclosed by a dotted line. Its lumen is divided into compartments by the anastomosing processes seen in Fig. 1.

i. Duct of Wirsung also surrounded by a dotted line, and divided into compartments. The dotted line is double at the left of the figure, as the exact limit of the duct could not be determined.

c, *d*. Plain muscular fibers, partly surrounding the ampulla and ducts on the side toward the pylorus.

g. All the interior not surrounded by the dotted lines belongs to the ampulla, and is greatly divided by folds and processes.

Fig. 5. Magnified 20 diameters, stained in hæmatoxylin. Section like the preceding, but nearer the aperture of the ampulla. This figure is given to show the exceeding complexity and sieve-like division of the ampulla by its anastomosing folds and processes.

d, and *e*. The thin edge of the muscular coats prolonged toward the summit of the ampulla.

Fig. 6. Longitudinal section of a single minute process, like that near *g*, fig. 5; stained in hæmatoxylin. Many simple glands dip down into the surface: they are merely depressions, for their epithelium is identical with that covering the general surface of the process. ×250.

m. A glandular depression becoming double.

n. Simple glandular depressions.

o. Cross section of one of the preceding.

q. Substance of the process made up mostly of adenoid tissue, containing many deeply stained nuclei.

abuts squarely against the duct. On the opposite side it curves, following the direction of the ductus choledochus. It tapers toward the extremity, but ends somewhat abruptly (Pl. XIV., Fig. 1, *d*, *e*). The wedge of muscular fibers between the ducts is made up partly of longitudinal, and partly of circular fibers. Near the external surface of the longitudinal layer, some of the fibers are sent straight between the ducts, and other, apparently special, fibers wind round the two ducts and form a common sphincter. Still other fibers pass around the ducts separately, and thus form special sphincters. The one which belongs to the duct of Wirsung is most marked.

On the internal surface of the ducts appear very many thin folds. These may originate on any part of the internal surface, and their free edges are always directed toward the orifice of the duct. Not only are the folds very numerous, but they anastomose and apparently give rise to secondary folds, thus making a most complex net work, and the complexity increases toward the orifice.

The walls of the ducts in their passage through the coats of the intestine, are composed mostly or entirely of areolar tissue. Processes of this tissue extend into the valvular folds spoken of above, and give them a strong framework.

The ampulla is also furnished with very many folds. These may arise from any part of its surface, and are like the folds in the ducts always directed *toward* its orifice. The folds anastomose, or arise partly from the wall of the ampulla, and partly from the surface of some other fold, or a large fold may give rise to secondary ones. The attachment of these folds and those in the ducts is somewhat similar to that of the valves in the veins (Pl. XIV., Fig. 1). In cross section the appearance is as if very many anastomosing trobeculæ were stretched across the cavity of the ampulla, and the lumen of the terminal part of the ducts which open into it (Pl. XIV., Figs. 4, 5).

In 1727, Duvernoy (9,346) described a reservoir, the ampulla of Vater, between the coats of the duodenum, in the *Chatpard*,* into which emptied the ductus choledochus and the duct of Wirsung. This reservoir was beneath a prominent papilla, and

* I have been unable to decide which one of the cats was meant by Duvernoy. He says of the *Chatpard* in question, *Catus pardus sen Catus montanus Americanor*, implying at least that it was an American felis. But in Cuvier and all other systematic works where *Chatpard* is defined, it is called *Felis Serval*, of South Africa and Senegal.

opened at its summit by a single orifice into the lumen of the intestine. "*In quo bilis et succus pancreaticus invicem permisceri videntur, antequam in cavum intestini effluant.*" In 1802 was published the description of the same condition in the elephant (39). (See the quotation from Owen, in an earlier part of this paper, describing the ampulla of the elephant.) A few years later, in 1819, appeared the description by Tiedemann of a reservoir in the seal (*Phoca vitulina*) like that in the elephant (32, 350). The first description of the ampulla in the domestic cat, so far as I know, is that given by Cuvier (5,520), where he says: "The ductus choledochus dilates between the muscular and mucous tissues of the duodenum, and its walls present several small culs-de-sac, which make the cavity anfractuous. It is at the bottom of one of these culs-de-sac that the pancreatic duct opens."

Most authors consider the ampulla as an enlargement of the ductus choledochus, but Hyde Salter says of the ampulla in man: "Since the mucous membrane lining the ampulla is of the same structure as that lining the intestine, and unlike that lining the ducts, these latter must be said to open by two distinct orifices at the base of the papilla and not by one at its apex as is usually described; in fact, the lining of the cavity of the papilla is part of the general mucous surface of the duodenum (27, 85)." Bernard (1,551–2) says of Pl. XIV., Fig. 2, that the ductus choledochus opens at the bottom of the ampulla, and that from the appearance of the epithelium the membrane lining it should be considered as the continuation of that lining the duct of Wirsung. In Fig. 3, where the ductus choledochus extends almost to the surface of the duodenum, he says of the pancreatic duct which opens at the base of the ampulla: "Point d'abouchement du conduit pancreatique properement dit dans l'ampoule de Vater, qui n'est que sa continuation." As the condition just described in man is the normal one in the cat, so far as the relative extent of the two ducts is concerned, doubtless one might say with equal propriety that the ampulla in the cat is only a continuation of the duct of Wirsung (Pl. XII., Fig. II., 8, 6; Pl. XIV., Fig. 1 and 3, h).

In my own investigation on the cat's ampulla, it was found impossible to determine in transverse sections whether a given part belonged to the ductus choledochus, the duct of Wirsung, or the ampulla proper, as the epithelium etc. seemed to be

identical in character in all parts of the section. Hence it was necessary to devise some means of distinguishing the different parts. At first red was injected into one duct and blue simultaneously into the other; but the fluids so mingled in the ampulla that it was impossible to determine the exact limits of either duct. It was found, however, that if only the duct of Wirsung was injected, none of the mass got into the ductus choledochus, hence in transverse sections uninjected parts were known to belong to that duct. In Pl. XIV., Figs. 1 and 4 were prepared in this way.* Not only did the epithelium of the ampulla and ducts appear identical, but their walls were covered with papilliform processes and simple glandular depressions, which seemed to be similar in the three situations (Pl. XIV., Fig. 6). The sections were stained in hæmatoxylin or picrocarmine, or unstained. As to the similarity of the epithelium of the duodenum to that of the ampulla in the cat, there seems to be but very little; they are certainly not identical. 1. The cells of the ampulla do not have a striated or hyaline border as do those of both the villi and crypts of Lieberkühn, Quain (25,362), Stricker (31,388). 2. Goblet cells are rarely or never found in the ampulla. With a power of 675 diameters, I have carefully examined the epithelium of all parts of the ampulla, following it to the level of the crypts of Lieberkühn, but neither goblet cells nor those having a striated border could be found, although in the same section the striated border of the cells of the villi was so plain that they looked almost as though they were ciliated, and goblet cells were very plentiful both in the villi and the crypts of Lieberkühn.

Turning for a moment to the cross sections of the duct of Santorini in its passage through the intestinal wall, it is seen to be divided into two compartments in the first section (Pl. XIII., Fig. 1); but in a section nearer the orifice the divisions are numerous, and the appearance is like the cross sections of the ampulla of Vater (Pl. XIII., Fig. 2). The epithelium, the papilliform processes, and the glandular depressions of this duct within the intestinal wall are similar to those in the ampulla.

The anastomosing folds and processes in the ampulla, the

* The extent and course of the ducts within the intestinal wall are much more easily determined in microscopic investigations if the duct of Wirsung be first injected with plaster of Paris colored blue, and after it has set, the ductus cholechodus may be injected with a similar mass colored red. The whole should be put into strong alcohol for half a day or more.

duct of Wirsung, and the ductus choledochus, being arranged somewhat as are the valves in the veins, allow a flow toward the orifice into the intestine, but greatly impede one in an opposite direction. It would probably be impossible for any solid matter to get into either duct, for it would be caught by some of the folds. The duct of Santorini in its passage through the wall of the intestine is also well guarded by valvular folds with their free edges toward the orifice, and is therefore well calculated to prevent any regurgitation of liquid or the entrance of solid substances. In this duct, the folds are seen to increase in number toward the orifice, as is the case with the ductus choledochus and the duct of Wirsung (Pl. XIV., Fig. 1, and Pl. XIII., Figs. 1 and 2).

The duct of Santorini seems to be kind of a reserve, and it may be the main channel for carrying the pancreatic juice, as is shown by its occasional great size in the cat and in man (1,389), while in the dog it is normally the larger (1,386; 22,510). Doubtless, in any case if the duct of Wirsung becomes clogged, it would assume the entire office of both ducts. In the fœtal dog and cat two ducts are of very nearly the same size and appear to be potentially of equal importance.*

In conclusion, it seems to me that the weight of evidence is greatly in favor of considering the ampulla of Vater as an appendage of the ductus choledochus or of the duct of Wirsung, and not of the duodenal mucous membrane. And, as the ampulla has been found so constantly whenever the two ducts enter the intestinal wall separately, and open by a common orifice, I would suggest that Duvernoy be followed in his opinion, viz., that the ampulla belongs to *both* ducts.

SUMMARY.

1. The pancreas in the cat is constantly provided with two anastomosing ducts of unequal size which open separately into the intestine.

2. One of the ducts, usually the larger, after passing through the muscular coat of the duodenum, opens into its lumen through a contracted orifice common to it and the ductus choledochus.

3. The ducts have been named, from their size, principal and

*It would be of the greatest interest to know whether the pancreatic ducts are developed simultaneously, or one earlier than the other, as is the case in the chick (11,133).

accessory; but the comparative size is variable; and as position in morphology is doubtless of much greater importance than size, names should be used which have no reference to size. Accordingly, in this paper, the following names, sanctioned by high authority, have been used:—Duct of Wirsung, for the one opening into the intestine with the ductus choledochus, and duct of Santorini for the one opening independently.

4. The pancreas in the cat is covered on both sides by peritoneum.

5. Occasionally there occurs a reservoir for the pancreas, like the gall-bladder for the liver, which communicates freely with the duct of Wirsung. The presence of this anomaly seems to have been noted but once before, and then, as in the present case, in the domestic cat.

6. The pancreatic ducts are composed of a lining of columnar epithelium, a middle layer of elastic tissue, and an external coat of areolar tissue or a tunica adventitia. The vascular supply is very dense, especially in the middle coat next the epithelium.

The structure is like that of gland-ducts in general as given by Robin (16), and somewhat comparable to the elastic type of blood-vessels as given by Stricker (37,200) and Ranvier (26,561).

7. As the ductus choledochus and duct of Wirsung pass through the longitudinal muscular coat of the duodenum they are provided by it with a common, and each with a special sphincter.

8. The ductus choledochus and the duct of Wirsung empty into a common reservoir, the Ampulla of Vater, situated between the muscular and mucous coats of the duodenum.

9. The Ampulla, and the terminal part of the ducts of Wirsung and Santorini, and the ductus choledochus are provided with valvular folds whose free edges are directed *toward* the orifices in each case.

10. The structure of the mucous membrane of the Ampulla is like that of the terminal part of the duct of Wirsung and the ductus choledochus, and not like that of the duodenum; hence, it should be considered, in the cat at least, as an appendage of the ducts and not of the duodenal mucous membrane.

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LABORATORY NOTES AND QUERIES.

1. Very excellent permanent preparations of the red blood-corpuscles of Amphibia may be made by Ranvier's method, as follows: Some blood is allowed to drop from a wound into about 200 times its volume of a saturated picric acid solution. After a few minutes the picric acid is carefully poured off, leaving most of the corpuscles at the bottom of the dish; a solution of picrocarmine is then poured over them, and allowed to stand a day or two. The picrocarmine is then poured off and the sediment put into acid glycerin (glycerin 100 parts, acetic acid 1 part). The corpuscles so treated will last a long time, and may be mounted in the acid glycerin at any time. The nuclei of the corpuscles are stained bright red, and the body light yellow. Corpuscles of *Menobranchus*, which are about twice as large as those of the frog, prepared in this way nearly a year ago, appear perfect as ever.

2. When tissues are imbedded in paraffin for making sections, the imbedding mixture gets into the meshes of the loose, external, connective tissue, and the mouths of the ducts, glands, etc., so that the outlines of the sections are greatly obscured, unless they are put into some medium that dissolves the paraffin. If they are to be mounted in glycerin, or some other fluids, this cannot be done except by tedious manipulation. The imbedding mixture may be kept entirely away from the tissue, by first dipping it into thick gum-arabic, and then putting it into strong alcohol for a short time. The alcohol hardens the gum, which forms a protecting coat, and also a mechanical support for the loose connective tissue around the outside. The gum may be dissolved from the sections by immersing them for an hour or two in 25 *per cent.* alcohol. Sections prepared in this manner may be cleared, and mounted in balsam or damar, by the usual method.

3. In a very able article upon the preparation of rocks and fossils for microscopical examination by R. Fritz Gaertner, in the April number of the *American Naturalist* for 1878, the advantages of slides measuring 25×45 mm. over those 3×1 inch, were stated to be as follows: (1) They can be rotated on the stage; (2) they are less liable to break if dropped; (3) they take up less room. It was also stated that this size was adopted by the New York State Museum of Natural History, and by lithologists and palæontologists generally, both in Europe and America.

These arguments seemed to me quite as valid as applied to microscopical objects in general; I therefore adopted this size (25×45 mm.) for my own preparations, and they have proved very satisfactory indeed.

S. H. Gage.